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Estimation of Household Energy Demand and Its Elasticities in Urban Ethiopia: A Case Study of Nakamte Town

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Abstract
This study looks into households' energy demand and its elasticities in Nakamte town. The objective of the study is to estimate household demand for the main energy sources (fuel-wood, charcoal, kerosene and electricity), and their elasticities of demand. The study used household-level survey data collected from 120 sample households in Nakamte town. A two- stage sampling procedure which consists of simple and systematic random sampling techniques was employed to select the sample households. The study used a Linear Approximated Almost Ideal Demand System model (LA/AIDS) to estimate household energy demand system. Estimates of the model were constrained to comply with neoclassical theoretical restrictions on demand, and the model was estimated using Iterative Seemingly Unrelated Regression (ISUR). The result shows that prices of energy sources significantly influence the energy expenditure shares of all energy sources. Demand for all energy sources are price elastic and all energy sources are substitutes. Except for charcoal, household total energy expenditure significantly influence energy expenditure shares of energy sources. All energy sources considered have expenditure elasticities greater than zero indicating no energy source is an inferior good for households in the study area. Furthermore, energy expenditure share of a particular energy source is significantly influenced by one or more of household characteristics such as sex and age of household head, education level of the wife and refrigerator ownership. Policy interventions aimed to change the household energy consumption pattern of the town need to focus on the estimated elasticities and household characteristics that significantly influence household energy demand.

Keywords: Household energy, Iterative Seemingly Unrelated Regression, Linear Approximated Almost Ideal Demand System, energy source, Nakamte town

1. Introduction

Urban households in Ethiopia use various sources of energy in different combinations, depending on the needs they satisfy, their availabilities, and household characteristics. Fuel-wood, charcoal, kerosene and electricity are the main alternative sources of energy that are consumed in different mixes by urban households in the country. However, majority of households in urban areas of the country still remain dependent on fuel-wood and charcoal for cooking purpose (Mulugeta, 2004).

With this massive use of fuel-wood and charcoal, factors causing high demand for these fuels in urban areas of Ethiopia remain unclear. However, there are two hypotheses concerning household fuel choice in developing countries. Firstly, it has been argued that households with lower incomes consume biomass fuels, such as wood and dung, while those with higher incomes consume energy that is cleaner and more expensive, such as electricity (Masera et al., 2000; Heltberg, 2005; Rajmohan and Weerahewa, 2007, Faye, 2002). Secondly, it has been argued that households in developing countries do not switch to modern energy sources, but tend to consume a combination of solid and non-solid fuels as their incomes increase (Masera et al., 2000; Chambwera, 2004, Mekonnen and Kohlin, 2008). While the choice of fuel by households is an economic decision that contributes to their welfare, it also contributes to environmental, economic and health problems (Chambwera and Folmer, 2006).

The urban energy demand is a more serious issue as compared to the rural energy demand in Ethiopia. With increasing urbanization over time, the demand for energy will also increase in the urban areas of the country. In addition, the rural-urban migration in the country contributes to the increasing demand for energy in urban areas.

The attempt to influence the existing urban energy consumption pattern of Ethiopia requires estimating household energy demand, its elasticity and the possible measures through which one can influence it. However, few studies were done with regard to household energy demand, and elasticities in urban areas of Ethiopia.

The objective of this study is to estimate household demand for the main energy sources and price and income elasticities of demand of the energy sources. The study helps policy makers to design demand side policies that encourage use of modern fuels while opting for measures that weakens reliance on traditional biomass fuels. Identification of factors that influence energy demand will facilitate smooth formulation of policy from three dimensions- health, economy and environment. Moreover, computation of expenditure and price elasticities plays a very important role in formulation of domestic energy policies. Not only are they important for domestic energy policies but are regarded as useful in the context of greenhouse gas abatement energy policies.

2. Review of Literature

This section attempts to summarize what up to now have been done either theoretically and empirically on consumer demand with special attention on household energy demand. **Theoretical Literatures**

2.1.1. Consumer Behavior and Consumer Demand Functions

Better understanding of the concepts of neoclassical consumer demand theory is required for empirical demand estimation in general, and for energy demand estimation in particular. Neoclassical economic demand theory assumes that consumer demand is derived from constrained utility maximization (Varian, 1992). The basic axiom of the utility maximization process is that a rational consumer will always choose a most preferred bundle of goods from the feasible set of consumption bundles allowed by his budget. The standard utility maximization problem stated by Varian (1992) and used to derive the consumer demand for a good is

Maximize $u = u(q)$

Subject to $\sum_{i=1}^{n} p_i q_i = m$

Where q is a vector of the n goods demanded, q_i is the quantity demanded of good i, p_i is the price of good i, and m is income or total expenditure. The solution to the above problem gives $q_i = f_i(p, m)$which is a system of Marshallian or uncompensated demand functions. Here, p is a vector of prices of goods demanded.

The dual to utility maximization is expenditure minimization (Varian, 1992). In the dual problem setting, the objective of the problem is expenditure minimization subject to a given level of utility.

Minimize $\sum_{i=1}^{n} p_i q_i = m$

Subject to $u = u(q)$

The dual problem setting provides the same solution of qi, but is denoted by $qi = hi(u, p)$, which is a system of Hicksian or compensated demand functions. Deaton and Muellbauer (1980a and 1980b) used this method to derive Almost Ideal Demand System.

2.1.2. Properties of Consumer Demand Functions

Deaton and Muellbauer reviewed the properties of consumer demand which provide reasonable restrictions to demand models (Deaton and Muellbauer, 1980b). In many empirical works, these restrictions have been tested to confirm the theoretical plausibility of estimated demand functions (Blanciforti and Green, 1983, Molina, 1994, Berck et al., 1997, Taljaard et al., 2003, Wadud, 2006, Janda et al., 2010). These properties are adding up, symmetry, homogeneity, and negativity.

Adding up property

The total value of both the Hicksian and Marshallian demands is equal to total expenditure.

$\sum p_i \, hi(u, p) = \sum p_i \, f_i(p, m) = m$ for$i = 1, - - - - n$

This property of demand provides a reasonable restriction, the so-called adding-up restriction. The adding up restriction implies that the weighted average of income elasticities is equal to unity such that $\sum w_i \, e_i = 1$, where e_i is total expenditure elasticity of good i and w_i is the corresponding budget share (weight).

With $w_i = \frac{p_i q_i}{m}$, the adding up restriction is reduced to $\sum p_i \frac{\partial q_i}{\partial m} = 1$

Homogeneity property

Homogeneity implies that the Marshallian demand functions are homogeneous of degree zero in prices and income, and Hicksian demands are homogeneous of degree zero in prices.

That is, for scalar $\theta > 0$, $hi(u, \theta p) = hi(u, p) = f_i(\theta p, \theta m) = f_i(p, m)$

The homogeneity property provides the homogeneity restriction which implies that the sum of the own-price elasticity and cross-price elasticities of good i, $\sum_j e_{ij}$ and total expenditure elasticity of good i, e_i is equal to zero. That is, $\sum_j e_{ij} + e_i = 0$ which can be further reduced to $\sum_j p_j \frac{\partial q_i}{\partial p_j} + m \frac{\partial q_i}{\partial m} = 0$

Symmetry property

The property of symmetry says that the cross-price derivatives of the Hicksian demands are symmetric, i.e. for all $i \neq j$, $\frac{\partial h_i(u,p)}{\partial p_j} = \frac{\partial h_j(u,p)}{\partial p_i}$

Negativity property

The *n-by-n* matrix formed by derivative of Hicksian demands with respect to prices is negative semi-definite such that all diagonal elements of the substitution matrix are non-positive. This means that an increase in the price of a good causes demand for the good to decrease or remain constant if the income effect is compensated.

2.1.3. Almost Ideal Demand System

Since Richard Stone (1954) who first estimated a system of demand equations derived explicitly from a consumer theory, there has been a continuing search for alternative specifications and functional forms of demand. Many models have been developed, such as the linear expenditure system (LES), Rotterdam model, Indirect Translog model, and AIDS model. However, the most important in current use, apart from the original linear expenditure system, are the Rotterdam model and the Translog model (Deaton and Muellbauer, 1980a). Both of these models have been extensively estimated and have been used to test the homogeneity and symmetry restrictions of demand theory.

AIDS model is the latest form of the systems of demand models. It was first developed by Deaton and Muellbauer in 1980 based on earlier models of systems of demand equations, which have their roots in the model that was first developed by Richard Stone in 1954. It has considerable advantages over Rotterdam and Translog models (Deaton and Muellbauer, 1980a). Since its invention in 1980, AIDS has been used in demand studies for the following closely interrelated purposes (Pogany, 1996): (1) approximation of unknown parameters; (2) test of the symmetry of cross-price elasticities; (3) test on the zero price homogeneity of a demand system; (4) test of separability of products (i.e., if cross- price elasticities are zero between two products, belonging to two separate commodity groups); (5) test of homotheticity (i.e., test if expenditure elasticities are unitary); (6) test of demand theory itself in light of practical results; and calculations of market shares in general equilibrium calculations.

The Cobb-Douglas utility function, reflecting additive preferences between subsistence and above-subsistence level consumption, is a root of AIDS (Pogany, 1996).

If consumption is divided between subsistence level "a" and above-subsistence or "bliss" level "b" for a given commodity, the Cobb-Douglas direct utility takes the following form:

$$V(q) = a^{1-u}b^{u} \quad ----------------------------------- (1)$$

where "$1-u$" indicates the proportion of subsistence and "u" the proportion of "bliss" level consumption. The indirect cost function, containing the utility levels derived from consumption may be written as follows:

$$C(u,p) = (p.a)^{1-u}(p.b)^{u} -----------------------------(2)$$

where p stands for the price vector.

In estimating expenditure levels, "$p.a$" and "$p.b$" may be replaced with general functions, $a(p)$and $b(p)$, respectively.

$$C(u,p) = a(p)^{1-u}b(p)^{u} ------------------------------ (3)$$

If the newly specified cost function remains linearly homogeneous in the functions a and b, which, in turn, remain linearly homogeneous in prices, the demand equations derived from it will be homogeneous of degree zero in prices. Since the Cobb-Douglas type utility function is closely tied to the linear expenditure system, cost functions based on it are called "general linear cost functions" (Pogany, 1996). In this type of cost function, expenditure shares are independent of prices, so it may also be called "price-independent general linear cost functions" (PIGL).

Monotonic transformation do not change the order of utility levels attributed to the various commodities in a utility function (Varian, 1992). Hence, a PIGL cost function may take a logarithmic form as follows:

$$\ln C(u,p) = (1-u)\ln a(p) + u \ln b(p) ------------------------ (4)$$

Such functions are called "price-independent general linear log" (PIGLOG) functions. PIGLOG cost function represents class of preferences which allow exact aggregation over consumers and the representation of market demands as if they were the outcome of decisions by a rational representative consumer (Deaton and Muellbauer, 1980a, Berck et al., 1997).

Deaton and Muellbauer began the derivation of the AIDS by specifying $a(p)$ and $b(p)$ for this skeleton version of the PIGLOG class cost function (Deaton and Muellbauer, 1980a). They specified the following functional forms for $\ln a(p)$and $\ln b(p)$.

$$\ln a(p) = a_0 + \sum_i \alpha_i \ln p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j -------------------(5)$$

$$\ln b(p) = \ln a(p) + \beta_0 \prod_i {p_i}^{\beta_i} ----------------------------- (6)$$

The choice of (5) and (6) functions is governed partly by the need for a flexible functional form. However, they are mainly selected because they lead to a system of demand functions with desirable properties. Substituting (5) and (6) into the PIGLOG function (4) yields the AIDS cost function:

$$\ln C(u,p) = a_0 + \sum_i \alpha_i \ln p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j + u\beta_0 \prod_i {p_i}^{\beta_i} ------------ (7)$$

where α_i , β_i and γ_{ij} are parameters.

$C(u,p)$is linearly homogeneous in p provided that $\sum_i \alpha_i = 1$, $\sum_j \gamma_{ij} = \sum_i \gamma_{ij} = \sum_i \beta_i = 0$.

The demand functions can be derived from this cost function. It is a fundamental property of the cost function that its price derivatives are the quantities demanded (Varian, 1992).

$$\frac{\partial C(u,p)}{\partial p_i} = q_i ----------------------------------- (8)$$

Multiplying both sides of (8) by $\frac{p_i}{C(u,p)}$ results in

$$\frac{\partial C(u,p)}{\partial p_i}\frac{p_i}{C(u,p)} = \frac{q_i p_i}{C(u,p)} = w_i ---------------------------- (9)$$

where w_i is the budget share of good i

Since the left side of equation (9) is an elasticity type expression, it may be written as

$\frac{\partial \ln C(u,p)}{\partial \ln p_i}$ ------------------------------------(10)

Thus, the logarithmic differentiation of the cost function (7) gives the budget shares as a function of prices and utility:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i u \beta_0 \prod_i p_i^{\beta_i} \text{ ------------------------ (11)}$$

where

$$\gamma_{ij} = \frac{1}{2}(\gamma_{ij} + \gamma_{ji}) = \gamma_{ji} \text{ ---------------------------- (12)}$$

For a utility- maximizing consumer, total expenditure X is equal to $C(u,p)$, thus substituting X in place of $C(u,p)$ in (7) and solving for u gives the indirect utility function u as a function of p and X.

$$u(p,X) = \frac{\ln X - a_0 - \sum_i \alpha_i \ln p_i - \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j}{\beta_0 \prod_i p_i^{\beta_i}} \text{ --------------------- (13)}$$

Substituting the result of u into (11) results in budget shares as a function of p and X

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \beta_0 \prod_i p_i^{\beta_i} \left(\frac{\ln X - a_0 - \sum_i \alpha_i \ln p_i - \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j}{\beta_0 \prod_i p_i^{\beta_i}} \right) \text{ ------- (14)}$$

This simplifies to

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln(\frac{X}{P}) \text{ --------------------------(15)}$$

These are the AIDS demand functions in budget share form.
where P is an aggregate price index defined as

$$\ln P = \alpha_0 + \sum_i \alpha_i \ln p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j \text{ -------------------(16)}$$

The restrictions on the parameters of (7) plus equation (12) imply restrictions on the parameters of the AIDS equation (15):

Adding up restriction: $\sum_i \alpha_i = 1, \ \sum_i \gamma_{ij} = 0, \ \sum_i \beta_i = 0$

Homogeneity restriction: $\sum_j \gamma_{ij} = 0$

Symmetry restriction: $\gamma_{ij} = \gamma_{ji}, i \neq j$

If these restrictions hold, according to Deaton and Muellbauer (1980), (15) represents a system of demand functions which add up to total expenditure ($\sum w_i = 1$), are homogeneous of degree zero in prices and total expenditure taken together, and which satisfy Slutsky symmetry.

While estimating the model, one faces the obvious problem- the non-linearity of the price index in (16). While looking for suitable approximations, Deaton and Muellbauer (1980a) suggested a linear approximation of the non-linear AIDS model by specifying a linear price index given by

$$\ln P^* = \sum_i \overline{w_i} \ln p_i \text{ --------------------------------(17)}$$

where $\overline{w_i}$ is the i^{th} good average expenditure share of households (Berck et al., 1997).

This leads to the so-called Linear Approximated Almost Ideal Demand System (LA/AIDS), which is obtained by substituting (17) into (15)

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln(\frac{X}{P^*}) \text{ ------------------------- (18)}$$

2.2. Empirical Literatures

Household energy choice and energy demand in Ethiopia has been examined by a number of empirical studies. Kebede et al (2002) made an in-depth analysis of costs of different energy sources and their affordability in urban Ethiopia. They found that while kerosene is relatively cheap even for the very poor, electricity is extremely expensive even for the non-poor. Their estimation of household energy demand modeled by AIDS indicated that all fuels considered by the study have positive income elasticities. Computation of own-price elasticity revealed that firewood, charcoal and kerosene are price elastic. In addition, the cross-price elasticities showed that increase in the price of a traditional fuel mainly shifts demand towards other traditional fuels rather than towards modern fuels. However, the effect of an increase in the price of traditional fuels on the consumption of modern fuels is not clear. The study concluded that Ethiopian urban households are at a very low level with respect to a transition to modern fuels.

Faye (2002) conducted an analysis of household energy demand and consumption pattern in selected urban areas of Ethiopia. The analysis indicated that the use of traditional fuels dominates households' consumption pattern. He subdivided energy consumed by households into traditional and modern, and analyzed the energy consumption pattern using probit model. The analysis depicted that the probability of consuming traditional fuels declines with increase in income and the prices of the traditional fuels, and increases with the increase in prices of the modern fuels. On other hand, the probability of consuming modern fuels increases with increase in income and prices of the traditional fuels, and declines with an increase in modern fuels prices. Moreover, CLAD estimation of demand functions using micro data indicated that demand for all forms of energy are price elastic. Cross-price elasticities showed that kerosene is a substitute for both charcoal and firewood, whereas electricity is a substitute for all the three. Charcoal and firewood are complements. It was noted that household size is identified as the most important variable that increases demand for all forms of energy, and the use of traditional fuels decreases with level of urbanization.

Abebaw (2007) employed the Tobit model to assess why some household use more fuel-wood than others using cross-sectional survey data from households in Jimma town. The result of the Tobit model revealed that the relationship between per capita income and per capita fuel-wood consumption is non-linear, and that per capita fuel wood consumption is inversely related with household size and education of the household head. The result further indicated fixed asset ownership (like refrigerator) has a significant positive effect on per capita charcoal consumption. The study concluded that energy policy and development projects aimed at reducing fuel-wood dependency in urban areas of Ethiopia should work not only to increase the supply of modern energy but also reduce poverty to the poor households.

Mekonnen and Kohlin (2008) used multinomial logit model and random utility theory to investigate determinants of household fuel choice in major cities in Ethiopia. They found that urban households tend to increase the number of fuels they use as their incomes rise instead of completely switching from the consumption of traditional fuels to modern ones. Further, the analysis showed that fuel types such as wood are not inferior, as opposed to the energy-ladder hypothesis. They were able to conclude that households tend to switch to a multiple fuel-use strategy (fuel stacking) as their incomes rise due to a number of factors, including preferences, taste, dependability of supply, cost, cooking and consumption habits, and availability of technology.

Gebreegziabher et al (2010) investigated urban energy transition and new technology adoption as a way of reducing the pressure of urban centers on rural areas. A bivariate probit model was estimated to determine the factors underlying the use of electric mitad cooking appliances and wood stoves, and a household's choice of a specific fuel source. The finding suggested that in addition to prices of related goods, household income (expenditure) and other household characteristics (such as family size and age and education of household head) are important variables explaining household's choice of a particular fuel. Nevertheless, the relative importance of factors varied from one fuel source to the other. Improvement in income and education enhance the likelihood that a household would use electricity and reduce its consumption of wood. However, the finding does not support the energy ladder hypothesis. Moreover, probit regression results on household's fuel choice suggested that charcoal and kerosene, as well as wood and electricity are substitutes.

With the application of the LA/AIDS to analyze rural energy demand of households using panel data in an energy mix context, Guta (2011) found that households are inclined to choose cleaner, efficient, and advanced fuels than inferior fuels in their energy mix as their total expenditure increases. However, rural households have little incentive to diversify their energy consumption from firewood to available alternatives due to the free availability of fuel-wood. He concluded that complete energy transition from inferior fuel use to modern fuels requires holistic social, economic, cultural, and even ideological changes of the whole society.

The review of empirical studies on estimation of household energy demand and elasticity in Ethiopia show the existence of difference between results, defects in the methods employed to deal with the problem, failure to stick to theoretical restrictions in demand estimation and non-existence of study on the issue in some urban areas of the country where there is high linkage between environmental problems and urban household energy demand. Above all, the study of urban household energy demand estimation in small towns of Ethiopia has been overlooked by all existing empirical literatures. However, from the review of these empirical studies we also observe that there is uniformity on the relative importance of AIDS in the area of household energy demand estimation. Thus, this study attempts to estimate demand for energy goods using AIDS model by imposing theoretical restrictions in demand estimation and handling the problem of zero consumption of some energy sources.

3. Methodology of the Study

This part briefly explains the research methodology used in this study including types and sources of data, method of data collection, sampling design and specification of models and their estimation procedures.

3.1. Data and Sample Design

This study relays mainly on the primary cross-sectional data. The primary data needed for the study mainly focused on at-home consumption of sources of energy (fuel-wood, charcoal, kerosene and electricity) and household characteristics. A questionnaire was used to collect data, and it was administered to heads of households through interviews by trained enumerators. It is known that households do not keep records of their total expenditure, expenditure on each energy source and incomes obtained from different sources. So, the household survey entirely depended on recall method.

Two-stage sampling procedure was applied to select the required number of sample households. First, sample kebeles(sub-towns) were selected randomly. To do so, the kebeles of the town were grouped as either center or distant kebele. Accordingly, Calalaki, Kasso, Burka Jato and BakanisaKase were grouped as center, while Darge and Bake Jama were grouped as distant. Two sample kebeles were selected purposively; one from the center and the other from the distant. In this way, Calalaki and Bake Jama were selected purposely as a sample of center and distant kebeles, respectively. Second, sample households (units of analysis) were selected from the sample kebeles (Calalaki and Bake Jama) in a systematic random sampling manner. This study applied a simplified formula provided by Yamane (1967) to determine the sample size at 95% confidence level and 5% degree of variability (Israel, 2012). In addition, 9% level of precision is recommended in order to get the sample size which represents a true population. The sample size determination formula provided by Yamane (1967) is as follows (Israel, 2012).

$$n = \frac{N}{1+N(e)^2} = \frac{4{,}246}{1 + 4{,}246(0.09)^2} \cong 120$$

Where $\boldsymbol{n}$ is the sample size, $\boldsymbol{N}$ is the population size of sample kebeles ($N = 4{,}246$), and $\boldsymbol{e}$ is the level of precision or sampling error ($e = 0.09$). There are 13,431 households in Nakamte town, among which 2,729 and 1,517 resides in Calalaki and Bake Jamakebeles, respectively (Nakamte City Administration, 2013).

3.2. Specification of Econometric Models and Estimation Methods

Two types of econometric models were specified and estimated following the concept of a two-stage budgeting approach: Engel model and Linear Approximated Almost Ideal Demand System (LA/AIDS) model. The idea behind a two-stage budgeting approach is that allocation of household budget occurs at two independent steps. At the first step, households allocate their expenditure on broad commodity groups such as food, energy and durables. At the second stage, group expenditure is further allocated to each elementary commodity under the group. For the purpose of this study, we assumed that there are only two commodity groups: energy and other goods. At the first stage, households allocate their total expenditure between energy and other goods. At the second stage, expenditure on energy determined in the first stage is further allocated among the various sources of energy (fuel-wood, charcoal, kerosene and electricity). At this stage, demand for any good belonging to the energy group must be expressed as a function of total expenditure on the energy and the prices of goods within the energy group. Thus, $q_F = f_{EG}(P_{EG}, E_{EG})$, where q_F is quantity demanded of fuel F, P_{EG} is a vector of prices of goods within the energy group, and E_{EG} is total expenditure on the energy group. A two-stage budgeting process can be represented by the following figure.

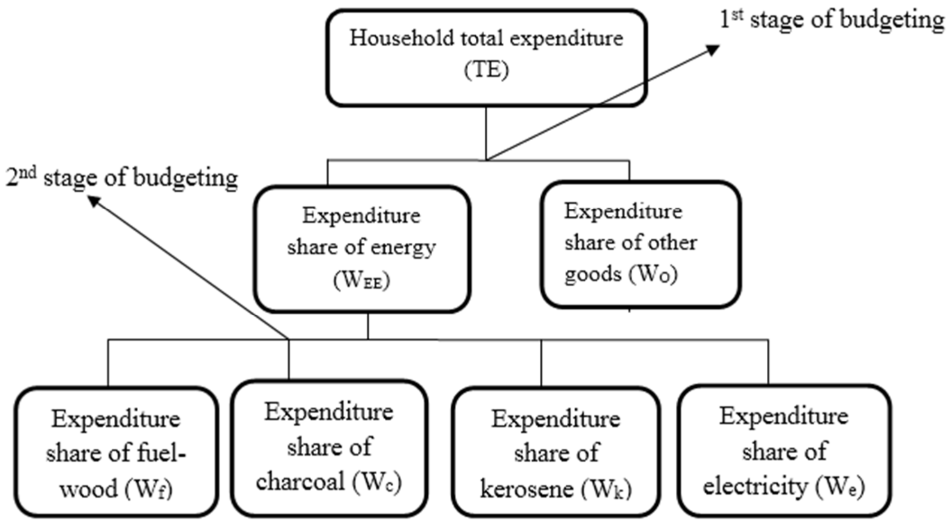

Figure 1: Theoretical framework of two-stage household budgeting adopted from Deaton and Muellbauer (1980b)

Following the first stage of budgeting, an Engle model was specified as a linear model. An Engel curve explains the relationship between the quantity demanded and income level of a consumer, keeping all prices and other factors constant. At the first stage, a given household is assumed to allocate his total expenditure (TE) between energy and non-energy groups. Therefore, expenditure share of energy for the i^{th} household is assumed to be a function of household total expenditure and the most important household characteristics (household size, education level of household head and wife, refrigerator and house owning status of household) so that the Engel model takes the following specification (Chambwera, 2004, Chambwera and Folmer, 2006, Rajmohan and Weerahewa, 2007, Bersisa, 2010):

$$W_{Ei} = \alpha + \beta \ln(dTEi) + \emptyset Zi + \varepsilon i$$

where ln is natural logarithm

W_{Ei} is the share of energy expenditure in total expenditure for i[th] household
dTE_i is household total expenditure deflated by consumer price index
Z_i is vector of household characteristics
α & β are parameters to be estimated
$\emptyset$ is vector of parameters to be estimated
ε_i is error term
The Engel model was estimated using OLS regression with robust standard errors assuming normally, identically and independently distributed error terms. After the estimation of the model, expenditure elasticity of energy demand was calculated using the following formula (Chambwera, 2004):

$$e_{Em} = 1 + \frac{\beta}{\overline{W_E}}$$

where $\overline{W_E}$ is average expenditure share of energy for sample households
The sign of β determines whether energy is a necessity or luxury. That is, if $\beta > 0$, energy is a luxury, if $\beta < 0$, then it is a necessity and if $\beta = 0$, energy consumption is income independent (Chambwera, 2004). The vector of coefficients $\emptyset$ allows us to assess the effects of household characteristics on the allocation of household total expenditure on energy.
For the empirical demand analysis, we used LA/AIDS. It was specified in line with the second stage of budgeting. As seen in its derivation, LA/AIDS is specified as (Pogany, 1996, Deaton and Muellbauer, 1980a, Deaton and Muellbauer, 1980b).

$$w_{Fi} = \alpha_F + \beta_F \ln({}^{TEE_i}/_{P*}) + \sum_j \gamma_{Fj} \ln p_j$$

We extended the LA/AIDS by incorporating the effects of household characteristics as explanatory variables. As a result, the LA/AIDS model takes the form (Chambwera, 2004, Chambwera, 2006).

$$w_{Fi} = \alpha_F + \beta_F \ln({}^{TEE_i}/_{P*}) + \sum_j \gamma_{Fj} \ln p_j + \phi_F X_i + \varepsilon_{Fi}$$

where w_{Fi} is household $i's$ expenditure share of fuel F in his total energy expenditure and is defined by

$$w_{Fi} = \frac{E_{Fi}}{TEE_i}$$

E_{Fi} is household $i's$ expenditure on fuel F and is given by

$$E_{Fi} = p_F q_{Fi}$$

TEE_i is household $i's$ total energy expenditure and is given by

$$TEE_i = \sum_F p_F\, q_{Fi}$$

F represents fuels consumed by the household (fuel-wood, charcoal, kerosene and electricity)
P* is the Stone price index and is defined by

$$\ln \mathrm{P}^* = \sum_F \overline{w_F} \ln p_F$$

$\overline{w_F}$ is fuel F's average of expenditure shares of sample households
P_j is price of fuel j
X_i is vector of household $i's$ characteristics
α_F, β_F & γ_{Fj} are parameters to be estimated
β_F measures the effect of household's total energy expenditure on the budget share of fuel F
γ_{Fj} measures the effect of the price of fuel j on the budget share of fuel F
ϕ_F is vector of coefficients of household characteristics
ε_{Fi} is error term associated with budget share of fuel F

While estimating LA/AIDS model, we faced the problem of substantial observations with zero expenditure share of kerosene. As seen in the descriptive analysis, all the sampled households use fuel-wood, and only very small number of the households do not use charcoal and electricity. On the contrary, many households did not use kerosene during the period of data collection, and some others do not totally consume it, implying zero values for the corresponding budget shares of kerosene. If the dependent variable has substantial zero values, OLS estimation produces inconsistent and biased parameter estimates (Gujarati, 2004). This problem was solved by using Heckman's (1979) two-step estimation procedure (Greene, 2002). First, the probit model was estimated to determine the likelihood of consuming kerosene. Thus, the dependent variable is binary ($Useke = 1$ if a household consume kerosene; and $Useke = 0$ if not). We estimated the probability that a household consumes kerosene or not as follows:

$$\left.\begin{array}{l} Prob(Useke = 1) = \Phi(x, \beta) \\ Prob(Useke = 0) = 1 - \big(\Phi(x, \beta)\big) \end{array}\right\}$$

where Φ is cumulative normal distribution of the error term
x is a vector of explanatory variables assumed to affect the probability of a household consuming kerosene or not
β is a vector of parameters to be estimated
The inverse Mill's ratio associated with kerosene was generated for each observation using the coefficients of

probit estimate ($\hat{\beta}$).

$\lambda_{Ki} = \frac{\phi(x_i,\hat{\beta})}{\Phi(x_i,\hat{\beta})}$

where λ_{Ki} is inverse Mill's ratio of kerosene

$\phi(.)$ is standard normal distribution density function

$\Phi(.)$ is cumulative function of standard normal distribution

The inverse Mill's ratio generated at this step was incorporated as an explanatory variable in kerosene demand equation so as to account for selection bias, and finally LA/AIDS model is specified as:

$w_{Fi} = \alpha_F + \beta_F \ln({}^{TEE_i}/_{P*}) + \sum_j \gamma_{Fj} \ln p_j + \phi_F X_i + \eta_F \lambda_{Fi} + \varepsilon_{Fi}$

where η_F is the coefficient associated to inverse Mill's ratio of fuel F and $\eta_F = 0$ if F is fuel-wood, charcoal or electricity, and $\eta_F \neq 0$ if F is kerosene.

We estimated the LA/AIDS model using Iterative Seemingly Unrelated Regression (ISUR) of Zellner (1962). This method allows us to obtain the simultaneous correlation of the error terms across equations and enables to impose cross-equation restrictions. We imposed the restrictions set by the theory of consumer demand. These restrictions are:

i. Adding-up restriction: $\sum_F \alpha_F = 1,\ \ \sum_F \gamma_{Fj} = 0,\ \sum_F \beta_F = 0$

ii. Homogeneity restriction: $\sum_j \gamma_{Fj} = 0$

iii. Symmetry restriction: $\gamma_{Fj} = \gamma_{jF}$

where F represents equation for each energy type, j stands for price of each energy source in each equation

Using the coefficient estimates of expenditure and prices, we can estimate expenditure and price elasticities of demand using the following formulas (Deaton and Muellbauer, 1980a, Berck et al., 1997, Taljaard, 2003, Chambwera, 2004).

Own price elasticity of demand: $\epsilon_{FF} = -1 + \frac{\gamma_{FF}}{w_F} - \beta_F$

Cross-price elasticity of demand: $\epsilon_{Fj} = \frac{\gamma_{Fj}}{w_F} - \frac{\beta_F \overline{w_j}}{w_F}$

Expenditure elasticity of demand: $\epsilon_{Fm} = 1 + \frac{\beta_F}{w_F}$

Integrated expenditure elasticities of demand for each energy source with respect to household total expenditure were also computed by multiplying the expenditure elasticity of energy demand from the first stage with the expenditure elasticities of demand from the second stage (Gundimeda and Kohlin, 2008 and Bersisa, 2010). This can be represented by equation as

$\epsilon_{iF} = e_{Em} \cdot \epsilon_{Fm}$

where ϵ_{iF} is integrated expenditure elasticity of demand for each energy source, e_{Em} is expenditure elasticity of demand for energy obtained from the estimation result of Engel model, and ϵ_{Fm} is conditional expenditure elasticity of demand for each energy source obtained from the estimation result of LA/AIDS model.

4. Results and Discussions

This section presents the empirical results of estimations of econometric models (Engel Curve and LA/AIDS).

4.1. Estimation of the Engle Model

We estimated the Engel model using OLS taking all observations into account. Using Smirnov-Kolmogorov test of normality and Breusch-Pagan/Cook-Weisberg test for heteroscedasticity, we found that the model suffers from the problems of non-normality and heteroscedasticity. As a result, OLS is no longer best linear unbiased and efficient estimator of the model. The problem of non-normality mainly arises from outliers, so we tested the existence of outliers using standard residuals. The test indicates that five observations were detected as outliers. Therefore, these observations were dropped, and we estimated the model again by OLS. Now, the model does not face the problem of non-normality, and significance testing of estimates becomes valid. In order to tackle the problem of heteroscedasticity, we used OLS estimation with robust standard errors. Robust standard errors can be calculated to compensate for an unknown pattern of non-constant error variance, and give more accurate p-values. The result of OLS estimation with robust standard errors is shown in table 1.

Table 1: OLS estimation with robust standard errors of the Engle model (N=115)

W_{EE}	*Coefficient*	*Robust standard error*	*P-value*
Ln of deflated total expenditure of household	*-0.151*	*0.016*	*0.000*
Household size	*0.006*	*0.003*	*0.029*
Education level of household head	*-0.004*	*0.002*	*0.039*
Education level of wife	*0.002*	*0.002*	*0.288*
Residence which household lives in	*0.011*	*0.019*	*0.566*
Refrigerator owning	*0.052*	*0.015*	*0.001*
Constant	*0.554*	*0.039*	*0.000*
$R^2 = 0.6473$			
$F(6, 108) = 22.7$			
$Prob > F = 0.000$			

Source: Author's calculation from survey data (2013)

As it can be seen from table 1, household total expenditure, household size, education level of household head and refrigerator owning condition of the household significantly influence the expenditure share of energy. The direction of coefficients of household total expenditure and household size is in line with the hypothesized signs. The expenditure share of energy decreases as household total expenditure goes up. This is consistent with earlier findings that the poor spend higher shares of their budgets on the energy than the rich do (Kebede et al., 2002, Chambwera and Folmer, 2007 and Gundimeda and Kohlin, 2008). Furthermore, the expenditure elasticity of energy demand computed from the estimation of first stage of budget allocation is about 0.15, depicting energy is a necessity good for households in Nakamte town. This means a 1% increase in household total expenditure increases energy budget share by about 0.15%. The share of energy expenditure is affected positively by the size of household. Expenditure share of energy decreases as household size increases. On the other hand, the share of energy expenditure decreases significantly as the education level of the household head increases. This might be due to the fact that educated household heads use energy efficiently so that their expenditure on energy is low. There is a positive relationship between the ownership of refrigerator and the share of energy expenditure. The increase in the share of energy expenditure as refrigerator ownership changes from non-owner to owner is attributed to higher use of electricity. This is similar to the finding of Chambwera and Folmer (2007) that the share of energy expenditure increases as the value of appliances owned by household increases.

4.2. Estimation of the LA/AIDS Model

The second stage of budgeting in our study involves the allocation of household total energy budget to fuel-wood, charcoal, kerosene and electricity. This is specified as a system of equations using LA/AIDS. The budget shares of fuel-wood, charcoal, kerosene and electricity in household total energy expenditure are the dependent variables of the model. Many observations have zero values of the budget share of kerosene; arising from non-consumption of this energy source. This may result in sample selection bias. Therefore, it is necessary to estimate the decision to consume kerosene by probit model before the estimation of LA/AIDS.

Table 2: Probit estimation of the decision to consume kerosene (N=120)

Dependent variable: Use kerosene =1 if a household uses kerosene; Use kerosene =0,otherwise			
Use kerosene	*Coefficient*	*Robust standard error*	*P-value*
Price of fuelwood	*-0.307*	*0.275*	*0.264*
Price of charcoal	*0.907*	*0.332*	*0.006*
Price of kerosene	*-3.066*	*0.914*	*0.001*
Price of electricity	*-0.302*	*0.360*	*0.401*
Ln TEE	*-0.965*	*0.985*	*0.327*
Age of household head	*-0.032*	*0.021*	*0.134*
Household size	*0.067*	*0.126*	*0.593*
Education level of household head	*0.057*	*0.058*	*0.324*
Education level of wife	*-0.059*	*0.051*	*0.252*
Employment status of household head	*0.205*	*0.351*	*0.559*
Refrigerator owning	*2.087*	*0.689*	*0.002*
Constant	*12.334*	*8.082*	*0.127*
Pseudo $R^2 = 0.6930$			
Wald $chi^2(11) = 48.31$			
$Prob > chi^2 = 0.0000$			

Source: Author's calculation from survey data (2013)

As can be seen from table 2, while coefficients of price of charcoal, kerosene and refrigerator ownership are significant at 1%, the other explanatory variables are found to be insignificant even at 10%, so they do not significantly affect the decision to consume kerosene. The prices of kerosene, fuel-wood and electricity are negatively related to the decision of consuming kerosene; but the price of charcoal affects the probability to consume kerosene positively. This suggests the substitutability between kerosene and charcoal as well as the complementarity between kerosene and fuel-wood and electricity in energy usage. However, this requires the computation of cross- price elasticities of demand for these energy sources. Moreover, owning refrigerator increases the probability of consuming kerosene.

Following the estimation of decision to use kerosene, we proceed to the estimation of the decision of how much energy budget is to be allocated to each energy sources. The inverse Mill's ratio generated from the estimation of probit model was incorporated in kerosene demand equation, and we estimated demand for each energy source by OLS regression separately. The OLS estimation result for energy expenditure share of kerosene shows that the coefficient of inverse Mill's ratio was found to be statistically significant, showing sample selectivity is a problem. Therefore, it should be included as a regressor in kerosene demand equation in the near time estimation of LA/AIDS by ISUR. To estimate demand for fuel-wood, charcoal, kerosene and electricity by ISUR, we imposed homogeneity and symmetry restrictions so that the estimates of parameters fulfill theoretical restrictions of demand theory. The sum of energy expenditure shares of energy sources ($Wf + Wc + Wk + We$) equals to unity, so attempting to estimate all equations in a system results in singular error matrix. A common procedure for handling the singularity problem is to drop an arbitrary equation and then estimating the remaining equations (Takada et al., 1995). Accordingly, we dropped kerosene demand equation from the system and the coefficients of kerosene demand equation were set free of homogeneity and symmetry restrictions. The coefficients of kerosene demand equation were in turn obtained by dropping any of the other demand equations and making the coefficients of the dropped equation free from the restrictions. ISUR estimates of parameters do not vary irrespective of which equation is dropped. SUR model assumes that error terms for a given observation may be correlated across equations of the system, but SUR estimator is efficient because it is a special case of the GLS estimator (Davidson and Mackinnon, 1999). Therefore, it does not share the problems of heteroscedasticity and serial correlation. The ISUR estimators are more efficient than single equation estimation methods such as ordinary least squares. Moreover, ISUR method of LA/AIDS estimation is particularly useful for testing homogeneity and symmetry properties which are basic to consumer demand theory.

Table 3: LA/AIDS estimation of demand for each energy source by ISUR (N=120)

Variables	*Wf*	*Wc*	*Wk*	*We*
Ln of price of fuel wood	*-0.276*** (0.020)*	*0.096*** (0.015)*	*0.057*** (0.012)*	*0.122*** (0.017)*
Ln of price of charcoal	*0.096*** (0.015)*	*-0.312*** (0.022)*	*0.075*** (0.014)*	*0.140*** (0.018)*
Ln of price of kerosene	*0.057*** (0.012)*	*0.075*** (0.014)*	*-0.227*** (0.018)*	*0.095*** (0.018)*
Ln of price of electricity	*0.122*** (0.017)*	*0.140*** (0.018)*	*0.096*** (0.017)*	*-0.357*** (0.028)*
Ln of deflated total energy expenditure	*-0.093*** (0.018)*	*-0.001 (0.017)*	*0.055*** (0.012)*	*0.039** (0.017)*
Sex of household head	*-0.070** (0.033)*	*0.033 (0.032)*	*-0.012 (0.021)*	*0.045 (0.030)*
Age of household head	*-0.001 (0.001)*	*0.002** (0.001)*	*-0.001 (0.001)*	*0.000 (0.001)*
Household size	*0.008 (0.005)*	*-0.006 (0.005)*	*-0.003 (0.003)*	*0.001 (0.005)*
Education level of household head	*0.001 (0.003)*	*-0.001 (0.003)*	*0.002 (0.002)*	*-0.002 (0.003)*
Education level of wife	*-0.007** (0.003)*	*0.007*** (0.002)*	*-0.003** (0.002)*	*0.003 (0.002)*
Employment status of household head	*0.001 (0.017)*	*0.007 (0.016)*	*0.000 (0.011)*	*-0.008 (0.015)*
Residence which household lives in	*-0.015 (0.031)*	*-0.016 (0.030)*	*0.001 (0.020)*	*0.028 (0.028)*
Refrigerator owning	*-0.052** (0.026)*	*-0.063*** (0.024)*	*0.023 (0.016)*	*0.092*** (0.023)*
Inverse Mill's ratio	*NA*	*NA*	*0.053*** (0.015)*	*NA*
Constant	*0.902*** (0.087)*	*0.214*** (0.081)*	*-0.125** (0.056)*	*0.016 (0.079)*
R^2	*0.7467*	*0.6589*	*0.5948*	*0.7152*
Chi^2	*356.26****	*239.16****	*195.09****	*314.18****

*Note: Standard errors are given in brackets, and ***, **, and * represent significance at 1%, 5% and 10% respectively*
Source: Author's calculation from survey data (2013)

Table 4: Correlation matrix of residuals

	Wf	*Wc*	*We*
Wf	*1.0000*		
Wc	*-0.3656*	*1.0000*	
We	*-0.5625*	*-0.3349*	*1.0000*
Breusch-Pagan test of independence: $chi^2(3)$ *= 67.458, Pr = 0.0000*			

Source: Author's calculation from survey data (2013)

The correlation matrix of residuals indicates that there is negative correlation between error terms, and Breusch-Pagan test of independence rejects the null hypothesis of no correlation between error terms of equations of the system. Thus, the use of SUR is more efficient than the estimation of demand equations separately by OLS.

Identifying variables that significantly influence demand for energy source is very important for policy making to address problems associated with use of bio-mass energy sources, such as fuel-wood and charcoal. In this regard, we discuss variables that significantly influence energy expenditure share of one or more of energy sources from table 3.

i. Fuel prices

In economic theory it is hypothesized that demand for a good is a decreasing function of its price and this requires own price elasticity of demand should be negative. As we see table 3, the energy expenditure shares of all energy sources are negatively related to their own price, but positively related to the prices of related energy sources. The prices are significant at 1% significance level for all energy expenditure shares. Energy expenditure shares of all energy sources are influenced more by their own prices than the cross-prices.

ii. Household total energy expenditure

The coefficient of deflated household total energy expenditure is significant at 1% for energy expenditure shares of fuel-wood and kerosene, while it is significant at 5% for energy expenditure share of electricity and insignificant for the share of charcoal. The energy expenditure shares of kerosene and electricity increase, while that of fuel-wood and charcoal decrease as household total energy expenditure increases. This complies with the descriptive finding that energy expenditure shares of kerosene and electricity increase, while that of fuel-wood decreases as we move up from low-expenditure to high-expenditure households and the energy expenditure share of charcoal is more or less equal for both groups.

iii. Sex of household head

The coefficient of sex of household head is significant only for the energy expenditure share of fuel-wood. Energy expenditure share of fuel-wood decreases when household is headed by male.

iv. Age of household head

It is assumed that elder household heads are believed to be reluctant to adopt modern technologies, such as kerosene burning and electric stoves. Therefore, it was hypothesized that elderly headed households demand less of kerosene and electricity, but more of fuel-wood and charcoal. But, the result of ISUR estimation shows that this variable significantly influences only the energy expenditure share of charcoal. As the age of household head increases, the energy budget allocated to charcoal increases. This might be due to households headed by elder need more of charcoal for warming space than households headed by young do.

v. Education level of the wife

The majority of women in Ethiopia allocate most of their time to domestic activities. As a result, they need energy sources which are convenient to them. Education equips women with the necessary knowledge how to use modern technologies as well increases their awareness about the possible negative effects associated with the use of biomass fuels (such as respiratory diseases from fuel-wood and charcoal use). Thus, education of the wife plays an important role in urban household energy transition since it helps them to adopt modern technologies. The result of ISUR estimation indicates that the coefficient of the variable is statistically significant in the energy expenditure shares of fuel-wood, charcoal and kerosene. Even though the coefficient is not statistically significant, it has the expected sign in the energy expenditure share of electricity. An increase in the education level of the wife leads to an increase in the energy expenditure shares of charcoal and electricity, but it leads to a decrease in the energy expenditure shares of fuel-wood and kerosene.

vi. Refrigerator ownership

As stated in chapter three, refrigerator ownership increases the amount of electricity consumption, but it decreases the frequency of using the other sources of energy. As a result, it was expected that it increases the energy expenditure share of electricity, but it decreases the energy expenditure shares of the other energy sources. As we see table 3, the coefficient of refrigerator is significant and consistent with the expected signs for the energy expenditure shares of fuel-wood, charcoal and electricity, but it is insignificant and inconsistent with the expected sign for the energy expenditure share of kerosene.

The so far discussed variables are main explanatory variables that significantly influence the demand for one or more energy sources focused by this study. The inverse Mills ratio, which was included as explanatory variable to correct sample selection bias for kerosene demand equation, is also significant. However, coefficients of size of household, education level and employment status of household head and residence type fail to be significant statistically in all energy expenditure shares of energy sources.

4.3. Elasticities of Household Energy Demand

Once we obtain the estimates of the coefficients of prices and expenditures, it is possible to compute price and income elasticities of demand. Price and income elasticities of demand are worthy to examine the effects of price and income on demand for each energy source and help the policy makers to formulate policies that address the problems associated with household fuel-wood and charcoal use. Hence, we computed price income (expenditure) elasticity of demand for each energy source as follows using the coefficient estimates of price and income obtained by ISUR estimation and average energy expenditure shares of energy sources.

4.3.1. Income Elasticities of Household Energy Demand

Table 5: Expenditure elasticities of demand from the estimation result of the LA/AIDS model

Energy items	*Expenditure elasticity*
Fuel-wood	*0.77*
Charcoal	*1*
Kerosene	*2.71*
Electricity	*1.18*

Source: Author's calculation from survey data (2013)

As can be seen from table 5 the expenditure elasticity is positive for all energy sources, indicating no energy source is an inferior good for households in the study area. This is consistent with the finding of Kebede et al (2002) and Faye (2002) that the budget elasticity is positive for both traditional and modern energy sources. The positive expenditure elasticity for all energy sources indicates that households broaden the type of energy source they use as their energy budget rises which tends to support the presence of multiple energy use (energy stacking hypothesis). Even though all energy sources are normal goods, they are not equally responding to the change in total energy expenditure. While the demand for kerosene and electricity are income elastic, demand for fuel-wood is income inelastic and demand for charcoal is unitary elastic. In other words, while kerosene and electricity are a luxury, fuel-wood is a necessity. Demand for kerosene is very sensitive to the change in energy expenditure, followed by electricity.

The above expenditure elasticities are calculated with respect to household total energy expenditure. We can also calculate integrated expenditure elasticities of demand with respect to household total expenditure by multiplying the expenditure elasticity of demand obtained in the first stage with expenditure elasticities of demand obtained in the second stage of budgeting (Gundimeda and Kohlin, 2008, Bersisa, 2010).

Table 6: Integrated expenditure elasticities of demand

Energy items	*Expenditure elasticity of demand from the 1st stage*	*Expenditure elasticity of demand from the 2nd stage*	*Integrated elasticity of demand*
Fuel-wood	*0.15*	*0.77*	*0.12*
Charcoal	*0.15*	*1*	*0.15*
Kerosene	*0.15*	*2.71*	*0.41*
Electricity	*0.15*	*1.18*	*0.18*

Source: Author's calculation from survey data (2013)

All integrated expenditure elasticities of demand are positive and less than one, indicating all energy sources focused by this study are necessities. Albeit the integrated expenditure elasticities of demand for fuel-wood and charcoal are lower as compared with that of kerosene and electricity, they remain positive which indicates the failure of energy ladder hypothesis in explaining the energy demand system of households in the study area.

4.3.2. Own-Price and Cross-Price Elasticities of Household Energy Demand

Table 7: Own-price and cross-price elasticities of demand from the estimation result of the LA/AIDS model

	Fuel-wood	*Charcoal*	*Kerosene*	*Electricity*
Price of fuel-wood	*-1.60*	*0.27*	*1.08*	*0.51*
Price of charcoal	*0.33*	*-1.87*	*1.71*	*0.60*
Price of kerosene	*0.15*	*0.21*	*-8.15*	*0.44*
Price of electricity	*0.36*	*0.39*	*2.64*	*-2.74*

Source: Author's calculation from survey data (2013)

Table 7 shows that all own-price elasticities of demand are negative and price-elastic. That is, the rise in the price of an energy source leads to a significant cut in the demand for that energy good. The own-price elasticity of demand in absolute term is highest for kerosene, followed by electricity, indicating demand for these energy sources are very sensitive to the change in their own prices. On the other hand, cross-price elasticities are positive revealing that all energy sources are substitute for each other. This finding is inconsistent with findings of earlier studies done in Ethiopia (Kebede et al., 2002, Faye, 2002 and Gebreegziabher et al., 2010). Households in Nakamte town use different energy sources for several tasks interchangeably. Except for baking injera[1], in which either fuel-wood or electricity are used, households can use either fuel-wood, charcoal, kerosene or electricity for cooking wet[2], preparing tea and coffee, heating bath water, etc. As a result, as the price of one energy good increases, households shift to the alternative energy sources. Cross-price elasticities are very relevant in providing information about the extent of sensitiveness of demand for a good to the change in the prices of related goods. Table 7 indicates that energy expenditure shares of fuel-wood, charcoal and kerosene respond highly to the change in the price of electricity as compared to the price of the other related energy sources. Therefore, change in the relative price of electricity plays an important role in influencing household energy demand system as well as in household energy transition.

5. Conclusion And Policy Implications

Based on the econometric analysis of cross-sectional data collected from sample households in Nakamte town, this study shows that household total expenditure, household size, education level of household head and refrigerator ownership are factors that significantly influence the allocation of household budget to energy. Expenditure share of energy decreases as household total expenditure increases. Moreover, expenditure elasticity of energy demand shows energy is a necessity for households in Nakamte town. Household size is positively

[1]Injera is Ethiopian staple food which is baked on circular pan
[2] Wet is usually eaten with injera

related with expenditure share of energy. While improvement in the education level of household head decreases the expenditure share of energy, possessing refrigerator increases the share. The result of ISUR estimation of LA/AIDS model indicates that prices of fuel-wood, charcoal, kerosene and electricity significantly influence their energy expenditure shares. Demand for these energy sources are price elastic, and the energy sources are substitute for each other. Energy expenditure shares of fuel-wood, charcoal and kerosene respond highly to the change in the price of electricity as compared to prices of other related energy sources. Therefore, change in the relative price of electricity plays an important role in influencing household energy demand system as well as in household energy transition. Except for charcoal, household total energy expenditure significantly influence energy expenditure shares of fuel-wood, kerosene and electricity. Computation of expenditure elasticities shows that no energy source is an inferior good for households in the study area, supporting the energy stacking hypothesis. However, the magnitudes of expenditure elasticities vary, putting fuel-wood as a necessity and kerosene and electricity as luxury goods. In addition to prices and household energy expenditure, energy expenditure share of a particular energy source is significantly influenced by one or more of household characteristics such as sex and age of household head, education level of the wife and refrigerator ownership.

Therefore, policy interventions aimed to change the household energy consumption pattern of Nakamte town need to focus on price of energy sources and household characteristics, besides income. The government should use prices of modern energy sources as policy instruments in order to influence the consumption of fuel-wood and charcoal. It is simpler to regulate the price of modern energy sources than that of traditional energy items. Moreover, empirical finding shows that demand for fuel-wood and charcoal respond highly to the change in price of electricity. Therefore, subsidizing residential electricity consumption could promote the substitutability of electricity, and reduce the consumption of fuel-wood and charcoal. Since household characteristics significantly influence household energy demand system, energy related policies should address micro level issues.

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